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THE MANIFESTATION OF THE FLIGHT-FUNCTION IN THE SILKWORM (*BOMBYX MORI*).

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The activities of the adult silkworm moth (*Bombyx mori*) are normally confined to those connected with the reproductive reflexes, mating and ovipositing.¹ The moth issues from its cocoon sexually mature and lives in a perfectly functional condition for several days without taking food and scarcely wandering from its birthplace. Its thoroughly domesticated condition and associated habits call for the exercise of but few of the usual insect instincts. In particular, searching for food and for mates having been dispensed with, the flight-function is a useless function and rarely manifest.

In general appearance, the newly emerged moth is a perfectly formed insect. A close inspection, however, shows vestigial mouth-parts, the taking of food having thereby become an impossibility. Otherwise, the various anatomical features are normal. The wings, particularly, are of perfect form and under perfect control so that the exercise of the flight-function is a possibility, though as stated the insects are rarely observed to fly.

"The presence of an organ," says Folsom,² "normally implies ability to use it. The newly born butterfly needs no practice preliminary to flight." The silkworm appears, from general observations, to be an exception to this rule. At any rate the non-flight habit has seemingly become fixed, absolutely so in the case of the female, but in the case of the male with exceptions and under special conditions to be herein noted.

This non-flight habit is such a common observation among silkworm breeders that investigators have made use of the wing of the silkworm moth to study indications of its structural degen-

¹ Kellogg, "Some Silkworm Moth Reflexes," *Biol. Bull.*, V., pp. 152-154.
McCracken, "The Egg-laying Apparatus in the Silkworm as a Reflex Apparatus," *Jour. of Comp. Neur. and Psychol.*, XVII., pp. 262-285, 1907.

² Folsom, "Entomology," p. 357.

eration on the basis of its being "functionally degenerate,"¹ and psychologists allude to the non-flight habit as indicating a loss of the "flying instinct."²

Especial interest therefore attaches to the fact that this apparently useless organ persists in a perfect form and under perfect muscular control.

Though slightly variable in the character of its venation, as pointed out by Kellogg and Bell, we do not know that the veins vary more than in the wings of moths of other species, and in comparing the wings of a long series of "non-fliers" with those of "fliers" I find no structural differences between the two lots. The wings appear, however, to be fundamentally non-useful, since both effectual mating and effectual ovipositing, the only adult activities, can be successfully accomplished without them. The de-winged silk-worm moth exhibits no inconvenience in these respects. Mayer-Soule³ found that in certain species males deprived of wings met with greater resistance from females when the females were deprived of sight. The female silkworm moth, however, exercises no selection between the normal and de-winged male, nor does the male between normal and de-winged female.

Although the wings are normally not used in flight, as pointed out, they are habitually fluttered preliminary to mating. This fluttering of the wings may effect a circulation of the air in the neighborhood of the moths so that the presence of the female with extended scent glands is more readily discerned by the male. However, the natural proximity of males and females under the usual conditions of silkworm breeding renders this use of but little importance.

The wings are also made use of in the "turning reflex." A moth placed upon its back instantaneously rights itself by bringing the forewings quickly together and thus exerting a pressure upon the surface. This procedure follows in the decapitated as well as in the normal moth, and though one rarely necessary under usual conditions it shows the perfect muscular and nervous control under which the wings are held.

¹ Kellogg and Bell, "Inheritance in Silkworms," I., Stanford Univ. Pub., No. 1, 1908.

² Oppenheim, "Mental Growth and Control," 1902, p. 99.

³ Mayer-Soule, "Some Reactions of Caterpillars and Moths," *Jour. Exper. Zool.*, Vol. III., 1900.

Since, therefore, the wings are present and are under perfect muscular and nervous control, what is apparently missing in the normal moth is the flight "instinct," or the disposition to set in motion those reflexes that make for flight.

A study of the habits of the male silkworm moth has been made, therefore, with special reference to the flight function and some interesting suggestive conditions have been observed.

As previously stated, the mating instinct is strong in the young male. It is at once aroused if a female is near and the numerous reflexes that effect mating are initiated. Upon leaving its cocoon, under ordinary conditions, the male seeks the near-by female. After several hours in copula separation takes place. The female then begins to oviposit, and the male seeks another female and thus passes from female to female throughout the few days of its existence. Thus we may say that the mating instinct once aroused is the dominating and controlling instinct. In the absence of the female the male behaves somewhat differently. If a young male moth is isolated in a closed box and in a room with no females present, it remains for several days in a perfectly passive condition, scarcely moving. On the fourth or fifth day the moth begins to flutter wildly about within the box, and upon removal of the cover soars into the air, circling about and sustaining itself upon the wing for from thirty seconds to several minutes. It comes to rest seemingly from fatigue and may, after a few seconds, during which the wings are vigorously fluttering, again take flight for a few minutes finally coming to rest again to remain wherever chance may find it until death ensues.

Having by chance observed this behavior in several male moths, I selected, at the height of the breeding season, a large number of males as they issued from their cocoons and placed them in a large well-lighted room by themselves, some individually within closed boxes and others exposed each by itself on a small tray. In many cases the moth remained perfectly quiet for several days, then wandered about with a fluttering of the wings, finally coming to rest and remaining in a quiet condition until death. By far the greater number, about seventy-five out of one hundred, behaved as in the cases previously noted. They fluttered about vigorously on the fourth to the eighth days and then soared upward.

Thus it was ascertained that many male moths were not powerless with respect to flight. The moth has not "forgotten" how to fly. It would appear, however, that, during the first few days of the life of the moth the flight reflexes are under inhibition and remain so during the exercise of the mating reflexes. Restrained from mating, however, as has been demonstrated, the flight instinct asserts itself, and the flight reflexes are "let loose" as it were. Neither natural selection, which by carrying a "flier" far from a mate, and thus leaving it without offspring, nor the discontinuance of the need for flight have served to eradicate the possibility of exercising the flight function.

As stated, the moths thus far experimented with were deprived of mates. Later, a large series of moths was isolated after mating had taken place. They were first allowed to mate normally. When they had voluntarily left the female they were isolated as before. The result was the same. When first isolated they were quiet. After several days had elapsed a large percentage entered into the "fluttering" condition and flight ensued.

During the very beginning of the "fluttering" condition if a female is brought near, the male is attracted to her and mating takes place. If, however, the fluttering condition is well under way the male pays no attention to the female but flutters past her or over her, it may be, and finally takes to wing.

It would seem, therefore, from the foregoing observations that the flight reflex is, at the time the insect leaves its cocoon, part of the moth's sum-total of inheritance but is merely under inhibition.

The mating instinct is, however, exercisable at once, that is, is immediately dominant. A sufficiently long inhibition of the mating instinct appears, in a large number of individuals, to augment the flight reflex. Furthermore, with the flight reflex released, the mating reflexes are, for the time being, inhibited, or at least manifestation of the flight reflex takes place only during suspension of the activities of the mating instinct, and during the manifestation of the mating activity, cannot be aroused.

This manifestation is wholly, however, without purpose, is purely non-adapted. It is a manifestation apparently of what

Wheeler refers to as "latent heredity."¹ "The vestigial instinctive action," says Wheeler, "presents itself as an act of racial or phyletic recollection and must, like the representations of individual memory, depend on psychological dispositions abiding in latency, just as the visibly morphological characters of the adult organism arise from the visibly physiological dispositions in the germ plasm. These dispositions must be inherited with great tenacity and persistency, since vestiges, both instinctive and structural, often remain latent for generations and then suddenly manifest themselves under stress of extraordinary stimuli."

In the case at hand, the "extraordinary stimuli," whatever these may be, that produce the manifestation are not external. The movement has every appearance of being "spontaneous," the release of "internal energy." The behavior here noted is strikingly parallel to that noted by Jennings with reference to lower organisms. "Often, perhaps usually in lower organisms," observes Jennings, "movement in a certain direction is due only to the release of inhibition. The organism moves in a given direction because it is moving from internal impulse, and because movement in this direction is not prevented."² Jennings observes, further, that "the behavior of the lower organism at any moment depends upon its physiological state at that moment."

Flight in the silkworm, manifesting itself as it does, without external stimulus and when the activities of the mating reflexes are suspended, is apparently a spontaneous movement dependent conceivably upon the physiological condition of the insect for the time being, and involves the awakening of a latent instinct.

In the presence of the female, the whole attention of the insect is monopolized for the time being with the impetus to mate. This "state" supercedes every other possible state and prompts or guides the insect to one line of conduct only. The action which is the normal consequent of this state is mating; all other possible actions are suppressed, and under normal conditions, as stated, habitually suppressed. The manifestation of the flight function under these experimental conditions shows that, though

¹Wheeler, "Vestigial Instincts in Insects and other Animals," *Amer. Jour. of Psychol.*, Vol. XIX., pp. 1-13.

²Jennings, "Behavior of Lower Organisms," p. 284.

this function is a part of the sum total of inheritance, the overwhelming development of the one instinct, that of mating, serves habitually to inhibit its activity. On the other hand, something has preserved both the wing structure and the flight function in spite of persistent non-use and natural selection, and although these have no relation to the preservation of the race in its present-day activities.

In the general conception of "instinct," its failure means extinction of the species.¹ In the case at hand, on the contrary its manifestation would mean extinction of the species. Its failure of manifestation is associated with the present-day life of the insect. Its manifestation under conditions herein observed attests the persistence in heredity of an ancestral function long after it has lost everything of a purposeful nature.

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¹ Jordan and Kellogg, "Evolution and Animal Life," p. 430.